

companies. Statistical tests found there was no evidence that the input price trends differ for the telephone industry and the U.S. economy for the full 1948-1992 period. It is extremely important to note that the same conclusion holds for the 1948-1984 and 1984-1992 subperiods.

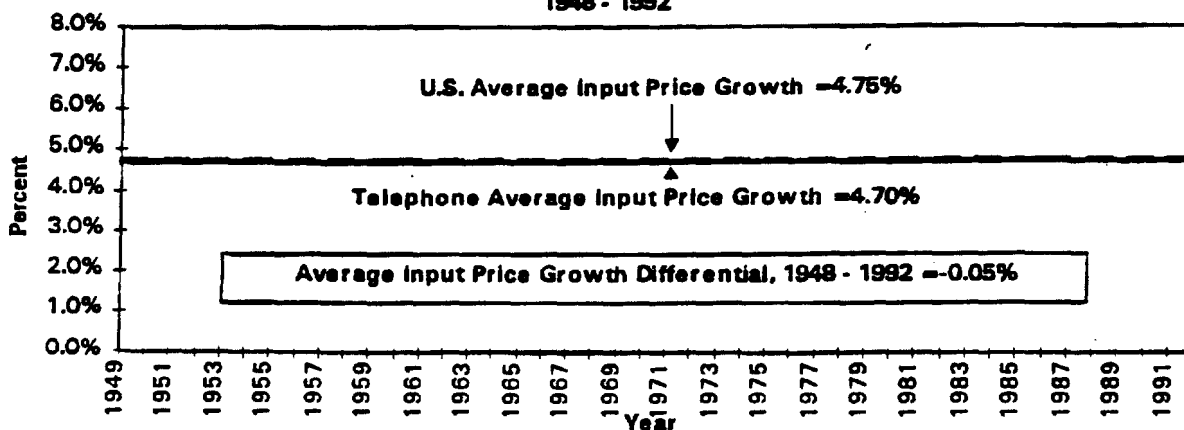
This means that any observed short-term differences in input price growth do not represent a difference in the underlying trends of input prices. The volatility of this series is so great that observed differences cannot be statistically distinguished from a difference of zero. This also means there is no statistical basis for using an observed short-run differential as a projection of expected future trends. This is illustrated in Charts 4 through 6.<sup>33</sup>

Chart 4 illustrates that the long-term average growth rates of telephone industry and U.S. economy input prices is essentially identical, resulting in a long-term differential of only 0.05%. Chart 5 shows the long-term differential and the annual values of the differential. It can be seen that there is substantial variability of the annual values around this long-term trend. Chart 6 illustrates that there was a great deal of annual volatility in the 1984-1992 input price growth differential. Annual values of the differential range from -7.8% to +7.7% during this period.

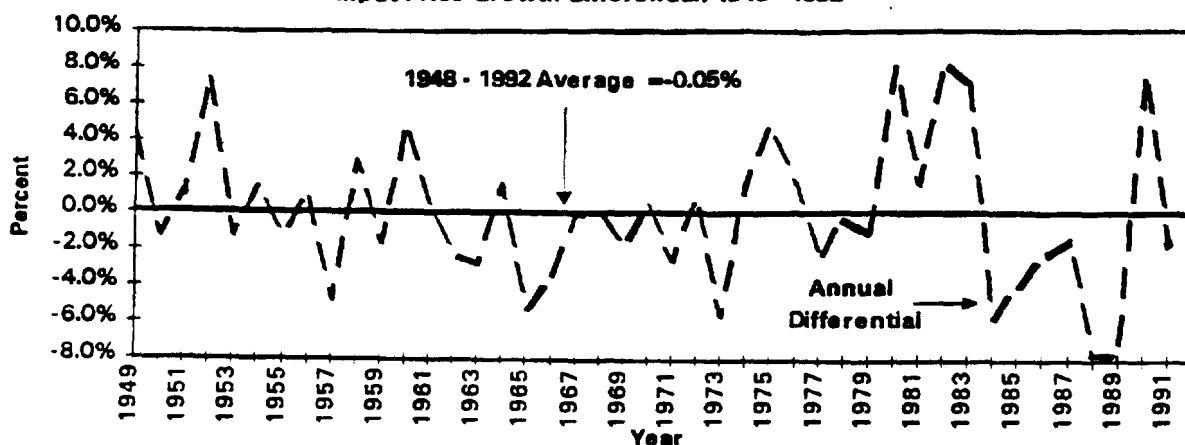
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<sup>33</sup> The first observed growth rate for the 1948 to 1992 period occurs in 1949--i.e., the growth in 1949 over 1948. Therefore, the first data point in Charts 4 and 5 is 1949. Similarly, in Chart 6, the first observed growth rate for the 1984 to 1992 period occurs in 1985.

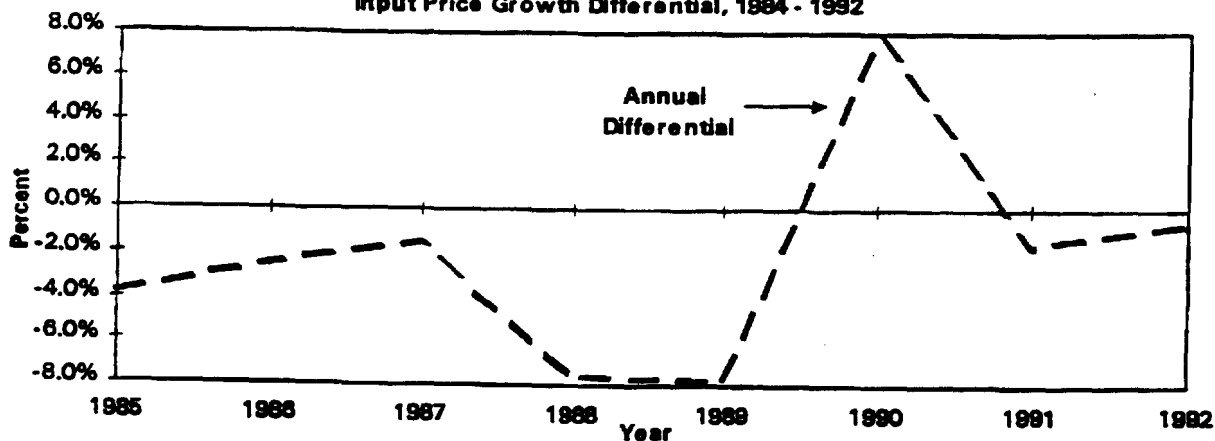
**Chart 4**  
**Average Telephone Industry and U.S. Economy Input Price Growth, 1948 - 1992**



**Chart 5**  
**Input Price Growth Differential, 1948 - 1992**



**Chart 6**  
**Input Price Growth Differential, 1984 - 1992**



The volatility of this series is so great that observed differences cannot be statistically distinguished from a difference of zero, meaning there is no statistical basis for using an observed short-run input price growth differential as a projection of expected future trends.

It is evident from Chart 5 that using the 1984-1992 differential as a basis for projection selectively chooses the only subperiod in the series where the differential was less than zero for a number of years. Events since 1989 indicate the differential has resumed its long-term pattern of random, volatile deviations around zero. The events producing the observed 1984-1989 input price differential are not likely to repeat themselves going forward. From 1984 to 1992 the LEC measured capital input price rose slower than the measured capital input price for the U.S. economy, and the LEC labor input price rose faster than the labor input price for the U.S. economy. But neither of these differences can be properly construed as a change in long-term trends. As I discuss below, because they cannot be expected to continue, they cannot form the basis for a forward-looking regulatory policy.

In particular, the short-term difference in measured capital input prices reflects the fact that measured LEC capital input prices put a much larger weight on interest rates than measured U.S. capital input prices, and the fact that up until 1993 the post-divestiture period has been a time of declining interest rates. The USTA study of LEC productivity growth used Moody's composite yield for public utility bonds as a proxy for the opportunity cost of

capital for all LECs.<sup>34</sup> This yield fell from 14.03% in 1984 to 7.56% in 1993. It had risen to an average of 8.3% in 1994. Subsequently interest rates have declined somewhat from 8.3%, but it is very unlikely that the U.S. economy will soon experience another period of prolonged interest rate declines of the magnitude experienced between 1984 and 1993.

Because short-term differences in one direction tend to be offset by subsequent short-term differences in the other direction, the inclusion of an input price growth differential term in the price cap offset based on recent short-term fluctuations in input prices is likely to be in the wrong direction. Therefore, the best estimate of the expected input price growth differential is given by the long-term differential of zero, not a projection of the 1984-1992 differential.

Tests for the 1959-1992 period. In addition to using a different data set, the other concern raised by Bush and Uretsky regarding the Christensen input price affidavit was that the data began in 1948 versus 1959 for the "NERA" data. Therefore, statistical tests were performed on the "Christensen" data set over the 1959-1992 period to demonstrate that the inclusion of the 1948-1959 period did not bias the test results presented in the Christensen input price affidavit.

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<sup>34</sup>Since the yield on public utility bonds reflects the cost of debt, but not equity, and since the cost of equity is typically higher than the cost of debt, this proxy will tend to understate the full opportunity cost of capital to the LECs. Moreover, since the cost of debt has recently fallen relative to the cost of equity, this proxy has declined relative to the full opportunity cost of capital to the LECs.

Over the 1959-1992 period, telephone input prices grew at an annual average of 4.9 percent versus 5.2 percent for the entire U.S. economy. Shown in Table A3.1 below are the statistical tests of the hypothesis that the trend in input price growth for the telephone industry equals the trend in input price growth for the entire U.S. economy for the 1959-1992, 1959-1984, and 1984-1992 periods.<sup>35</sup>

**Table A3.1**  
**Statistical Test of Hypothesis That Input Price Differential is Zero**  
**1959-1992**

Time Period	T-Statistic	Critical Value
1959-1992	0.40	2.04
1959-1984	0.41	2.08
1984-1992	1.30	2.36

As with the results presented in the Christensen input price affidavit for the 1948-1992 period, there is no statistical evidence that telephone industry and U.S. economy input price growth trends differ over the 1959-1992 period. Therefore, inclusion of the 1948-1959 period in the "Christensen" data set did not bias the results.

<sup>35</sup> For each time period, the first observed growth rate occurs in the second year of the period—i.e., the first growth rate for the 1959-1992 period is 1960.

## Conclusion

Pre-1984 telephone industry input price data based on the telecommunications industry study filed in Dr. Christensen's North Dakota testimony uses a different method for measuring capital input prices than his more detailed telephone industry TFP studies. Therefore, when using the combination of the telecommunications industry study for the pre-1984 period and the USTA LEC study for the post-1984 period (as in the "NERA" data), any observed differences in the input price differential could just as well be attributed to the different methodologies as to a "real" difference due to a "structural" change in the telephone industry/U.S. economy input price relationship. This renders the Bush-Uretsky results based on the "NERA" data meaningless.

The input price data set used in the Christensen input price affidavit is the most methodologically consistent and, thus, the most appropriate for measuring the relationship between telephone industry and U.S. economy input price trends. The affidavit demonstrated that there was no statistical evidence that input price trends differ for the telephone industry and the U.S. economy for the full 1948-1992 period, or for the 1948-1984 and 1984-1992 periods. Moreover, it has been demonstrated here that there is no statistical evidence that input price trends differ for the 1959-1992 or 1959-1984 periods.

This means that any observed short-term differences in input price growth do not represent a difference in the underlying trends of input prices. In particular, there is no statistical basis for using the 1984-1992 differential as a basis for projecting a differential for 1996 and beyond. Not only does this

represent the selective choice of the only subperiod in the series where the differential was less than zero for a number of years, but the volatility of the series is so great that observed differences cannot be statistically distinguished from a difference of zero.

**ATTACHMENT 2**

**ECONOMIC EVALUATION OF SELECTED ISSUES  
FROM THE FOURTH FURTHER NOTICE OF  
PROPOSED RULEMAKING IN THE  
LEC PRICE CAP PERFORMANCE REVIEW**

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**December 18, 1995**

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**ECONOMIC EVALUATION OF SELECTED ISSUES  
FROM THE FOURTH FURTHER NOTICE  
OF PROPOSED RULEMAKING IN THE LEC PRICE CAP  
PERFORMANCE REVIEW**

**I. BACKGROUND AND SUMMARY**

The *Fourth Further Notice of Proposed Rulemaking (FFN)* solicited comments regarding methods to establish a long-term price cap plan for the local exchange company (LEC) industry. This paper addresses four issues: (i) trends in LEC input prices and the direct measurement of LEC's unit costs (§57 and §61); (ii) the measurement of separate productivity growths for interstate, intrastate, regulated and nonregulated services, (§64, §65, and §70); (iii) AT&T's Historical Revenue (§80-83 and §88-89) and (iv) the consumer productivity dividend (§94-95).

In general, we find that post-divestiture point estimates of the difference between LEC and U.S. industry input price growth rates are unreliable. Measures of LEC productivity growth relative to the U.S. as a whole provide reliable targets for the annual price cap adjustment formula, and attempts to fine-tune such a formula using short-term changes in the input price differential will not lead to greater accuracy or larger welfare gains. Productivity measures must be calculated—as nearly as possible—at the level of aggregation of the entire firm. Because the production processes for interstate and intrastate (or regulated and unregulated) services are not separable, attempts to calculate service-specific productivity growth rates or to adjust total-firm TFP estimates for relative growth rates of particular inputs are futile. Finally, though the historical price and TFP methods of appraising past industry performance are based on the same basic economic theory and similar assumptions, (i) the TFP-based calculation is less sensitive to violations of those assumptions, (ii) the historical revenue approach does not have the theoretical support that the TFP and historical price methods possess, and (iii) the historical revenue approach requires many additional unrealistic conditions which do not hold in the telecommunications industry.

## II. LEC INPUT PRICES GROW AT THE SAME RATE AS U.S. INPUT PRICES

The  $X$  in a price cap plan should be chosen so that  $GDP-PI - X$  is a reasonable target for the future change in cost per unit of output for the regulated firm. Measurement of LEC and U.S. input price changes is thus necessary in order to translate changes in relative growth of total factor productivity (TFP)—which relate growth rates of output and input quantities—to relative changes in unit costs, which requires reliable information about input prices. Put simply, changes in cost per unit of output are given by the difference between the change in cost and the change in output quantity. Since the change in cost is simply the sum of the change in input price and input quantity, the change in cost per unit of output can be written as the difference between the growth of input prices and the growth of TFP.

The *FFN* seeks comments on three items related to the measurement of LEC and U.S. input prices and their role in the selection of an appropriate target value for  $X$ :

- Is the long-term difference between U.S. and LEC input price growth rates (the "input price differential") zero?
- Has the trend in LEC input prices or the input price differential changed since divestiture?
- Is it more desirable to measure LEC unit cost growth directly, rather than by comparing LEC TFP and input price growth to U.S. TFP and input price growth?

Our analysis once again confirms that the long-term trend of the LEC and U.S. input price differential is zero and that the trend has not changed since divestiture. We continue to believe that capital service prices are difficult to determine and, while adequate for their intended use in a TFP study, will result in historical input price growth differences that

cannot be calculated with sufficient accuracy to support forecasts of future input price growth differences.

**A. The Long-Term Trend of The Input Price Differential is Zero**

There is no genuine dispute in this proceeding that the long-term rate of growth of LEC input prices is the same as U.S. input price growth. As discussed in the attachment to the United States Telephone Association filing prepared by Christensen Associates, the input price series that is most methodologically consistent over time was filed in an affidavit by Dr. Laurits Christensen on February 1, 1995.<sup>1</sup> It combines (i) the Christensen Bell System study<sup>2</sup> for the 1949-1979 period, (ii) the USTA LEC study<sup>3</sup> for the 1984-1992 period, (iii) the Bellcore Report<sup>4</sup> for the 1980-1982 period and (iv) the North Dakota study<sup>5</sup> for the 1983-1984 period. In this data set (which we will call "Christensen 1" for convenience), the long run input price differential averages 0.1 percent and is not statistically significantly different from zero at conventional confidence levels.

In Appendix F to the *First Report and Order*, FCC Staff members C. Anthony Bush and Mark Uretsky (henceforth "Bush-Uretsky") cite a NERA analysis of a different set of Christensen data spanning the 1960-1992 period, which combines input price data from the Christensen LEC study for 1984-1992 and the Christensen North Dakota study for 1960-1984.<sup>6</sup> For convenience, we will label this data set "Christensen 2." Bush-Uretsky observe

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<sup>1</sup> L.R. Christensen, "An Input Price Adjustment would be an Inappropriate Addition to the LEC Price Cap Formula," Affidavit filed in CC Docket No. 94-1, February 1, 1995, Exhibit A (Christensen Affidavit).

<sup>2</sup> L.R. Christensen, D.C. Christensen, and P.E. Schoech, "Total Factor Productivity in the Bell System, 1947-1979," Christensen Associates, September 1981.

<sup>3</sup> L.R. Christensen, P.E. Schoech, and M.E. Meitzen, "Productivity of the Local Operating Telephone Companies Subject to Price Cap Regulation, 1993 Update," Christensen Associates, January 1995.

<sup>4</sup> Bell Communications Research Inc., *Econometric Estimation of the Marginal Operating Cost of Interstate Access*, Special Report SR-FAD-0900552, May, 1987.

<sup>5</sup> L.R. Christensen, "Total Factor Productivity Growth in the U.S. Telecommunications Industry and the U.S. Economy, 1951-1987," Schedule 3 to Direct Testimony, Case No. PU-2320-90-149, North Dakota Public Service Commission, 1990; U.S. Bureau of Labor Statistics, "Multifactor Productivity for the Private Business Sector."

<sup>6</sup> C.A. Bush and M. Uretsky, "Input Prices and Total Factor Productivity," *In the Matter of Price Cap Performance Review for Local Exchange Carriers, First Report and Order*, CC Docket 94-1, FCC 95-132 (March 30, 1995), Appendix F (henceforth "Appendix F").

that this input price differential series differs from Christensen 1 and that the average input price differential over the 1960-1992 period is larger than that for Christensen 1, averaging 0.7 percent. Bush-Uretsky's conclusion that "the various data series placed on the record by USTA are not all in accord that the long-run input price differential is, in fact, zero"<sup>7</sup> is based entirely on the Christensen 2 data set. They both use Christensen 1 and 2 data sets to argue that "the post-divestiture period represents a significant break from the past."<sup>8</sup>

The Christensen 2 data set was put together by NERA from publicly-available sources to test the hypothesis that the average input price differential was zero in the long run. However, as explained by Dr. Christensen, there are important differences in the measurement of input prices between the USTA LEC and the North Dakota studies. Hence, the Christensen 1 data set provides "the most theoretically consistent telephone input price time series available" because it minimizes the use of the North Dakota input price data for which capital prices were calculated using a different method.<sup>9</sup> Thus Bush-Uretsky's conclusion that because

Christensen has provided no justification for using a different version of the LEC input price series for the period 1960-1984 than NERA's version...we cannot accept Christensen's conclusion that the input price differential is zero<sup>10</sup>

is incorrect. Using the best available, most consistent measure of LEC input prices over the longest period available at the time, the difference between the growth rates of LEC and U.S. input prices is negligible (0.1 percent) and not statistically significantly different from zero.<sup>11</sup>

To test whether there is a statistically discernible difference between LEC and U.S. industry input prices, we performed four separate t-tests of the hypothesis that the mean

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<sup>7</sup> *Ibid.*, at 12.

<sup>8</sup> *Ibid.*, at 13-14.

<sup>9</sup> See the attachment to the United States Telephone Associating filing prepared by Christensen Associates.

<sup>10</sup> Appendix F at 13.

<sup>11</sup> However, as Dr. Christensen notes, there are significant methodological inconsistencies between the U.S. input inflation measure and his LEC input inflation estimates.

difference between the change in LEC (or telecommunications) input prices and U.S. industry input prices is zero assuming unequal variances. Table 1 shows that we cannot reject the hypothesis at the 95 percent confidence level, as each t-statistic is less than its associated critical value. Indeed, even at the 90 percent confidence level, we cannot reject the hypothesis that the input price differential—for the entire period or for the post-divestiture period—is zero. Thus, the data provide no statistically valid support for the use of an average input price differential different from zero. In other words, Christensen's conclusion that the LEC input price differential is zero is supported by the data.

**Table 1. We Cannot Reject the Hypothesis that LEC and U.S. Industry Input Prices Are Equal**

Study	Time period	Telco Mean Input Price Differential	U.S. Industry Mean Input Price Differential	t-Statistic	t Critical $\alpha=0.05$ , 2 tail
Christensen 1	1949-1992	4.7%	4.8%	0.06	1.99
Christensen 1	1985-1992	1.7%	4.0%	1.27	2.36
Christensen 2	1960-1992	4.7%	5.3%	0.79	2.01
Christensen 2	1985-1992	1.7%	4.0%	1.31	2.36

We performed our tests using both the Christensen 1 and Christensen 2 data sets. Again, the tests show that we cannot reject the hypothesis that the two series have the same mean over the longest possible periods: 1949-1992 for the Christensen 1 data and 1960-1992 for the Christensen 2 data. From these tests, we conclude that there is no evidence that the long-term input price growth rates for the LEC industry and U.S. industry in general are

different, and that no difference should be embodied in a value of  $X$  intended to represent a long-term industry average productivity target.

**B. The Input Price Differential Did Not Change Permanently at Divestiture**

Bush-Uretsky conclude that the post-divestiture average input price differential "is not consistent with a long-run trend of zero percent" and that "the input price differential for the post-divestiture period should be calculated using post-divestiture data." In addition, they assert—circularly—that "the input price differential for the 1984-1990 period should be based on data from that period" and that "[f]or purposes of calculating the historical X-Factor for the period 1984-1990 under a TFP framework, ...the input price differential for the 1984-1990 period should be used."<sup>12</sup> Under dispute is the robustness of that point estimate and whether it should be used as a forecast of future input price differentials. A key piece of evidence used to reach their conclusion is their test of Ad Hoc's unsupported hypothesis that divestiture explains the slow-down in LEC input prices relative to U.S. input prices during the 1984-1992 period:

We tested Ad Hoc's hypothesis that divestiture explains why LEC input prices appear to be growing at a substantially slower rate than economy-wide input prices during the 1984-1992 period....We performed several statistical tests...we conclude that divestiture is a major factor in slowing the rate of growth of telephone company input prices <sup>13</sup>

Bush-Uretsky claim to have tested two hypothesized relationships: (i) that changes in LEC input prices can be explained by U.S. input price changes, the level of Moody's public utility bond yields and the implementation of divestiture, and (ii) that changes in the LEC and U.S. input price differential can be explained by the level of Moody's public utility bond yields and divestiture. Simple ordinary least squares regression was applied to test each

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<sup>12</sup> Appendix F at 13-14.

<sup>13</sup> Appendix F at 13.

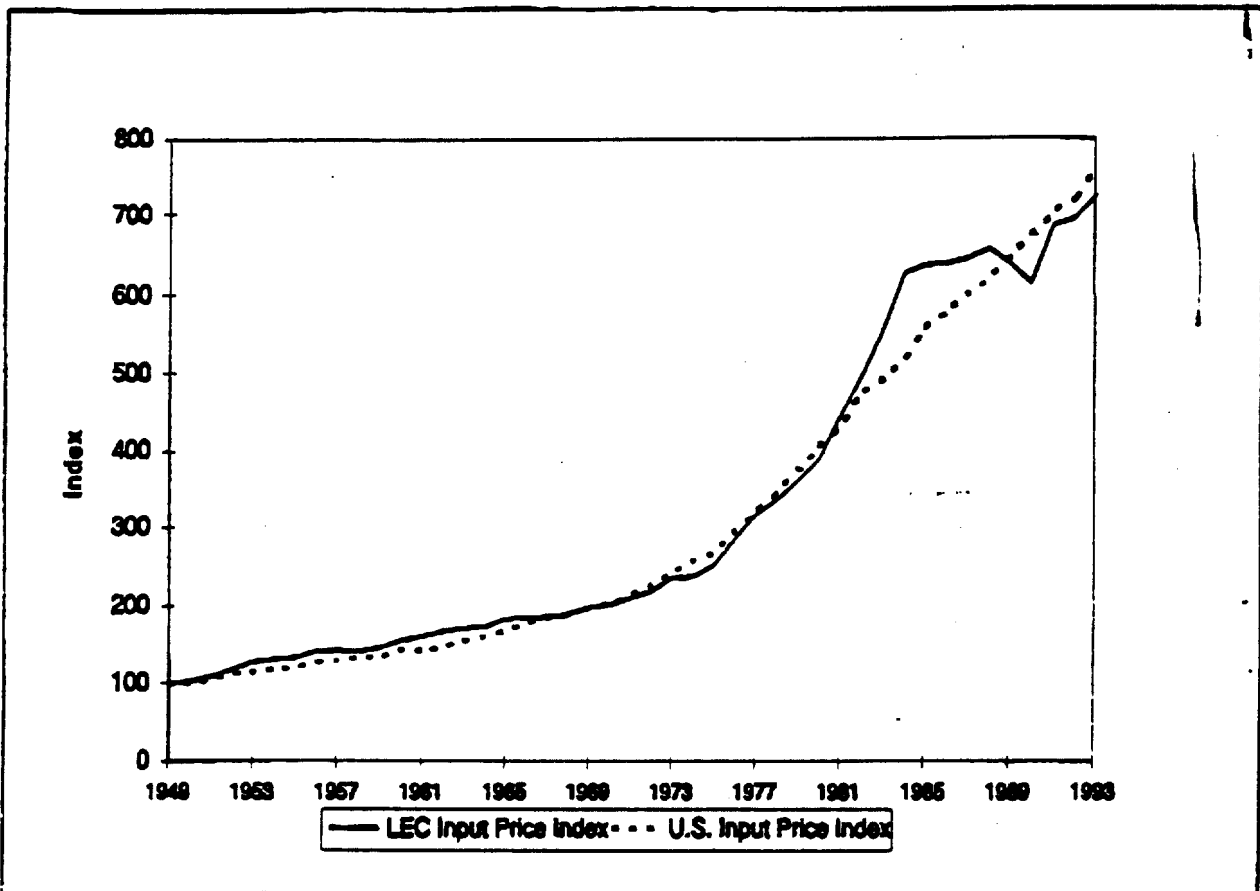
hypothesized explanation using both the Christensen 1 and 2 data sets described above, so that a total of four regression models were estimated.<sup>14</sup>

There are clear conceptual and statistical problems with the analysis performed by Bush-Uretsky. First, the Bush-Uretsky approach cannot be used to conclude that divestiture had any *causal* effect on either LEC input prices or the LEC and U.S. input price differential. Empirical economic analysis begins with an economic model that describes the relationships among economic agents, markets and economic activity. While a divestiture dummy variable is statistically significant in all four of their regressions, this result does not establish the hypothesis that changes in LEC input prices are related to divestiture, that the input price differential increased permanently at divestiture or that divestiture caused any change in LEC or U.S. input prices. The data appear to support the hypothesis that a temporary shift took effect between 1984 and 1990 but then reverted back to the normal historical pattern of input price changes. Indeed, simply adding an additional dummy variable to their equations to account for the 1990-1992 period would indicate that the relationship shifted back again so that the slower LEC input price growth rate in the 1984-1990 period should be regarded as an aberration, not a permanent change. See Attachment A. The fallacy of this type of reasoning—introducing a dummy variable into a regression with no theoretical support and inferring something from a statistical test of its coefficient's significance—was explained in a California proceeding by Dr. Gregory M. Duncan.<sup>15</sup> As illustration, using dummy variables and the Bush-Uretsky data set, Duncan showed (i) that the input price differential in the 1983-1992 period was no different from the 1960-1982 period, (ii) that the

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<sup>14</sup> The Christensen 2 data spanned 1960 to 1992 while the Christensen 1 data spanned 1949 to 1992. Bush and Uretsky reported that the binary variable used to represent divestiture was equal to "zero" for all years prior to 1984 and equal to "one" for 1984 through 1992.

<sup>15</sup> Direct and Reply Testimony of Dr. Gregory M. Duncan on behalf of GTE California Incorporated in California Public Utilities Commission Case No. I. 95-05-047. Dr. Duncan shows that Bush-Uretsky were, in fact, unable to test the hypothesis of whether the LEC and U.S. input price series deviate from one another in the long run for two reasons. First, both the U.S. input price series and the Moody bond yield series are endogenous in the model, and second the Bush-Uretsky procedure misuses dummy variable methodology. Dr. Duncan performed an ARIMA analysis and a cointegration test between Christensen's LEC and U.S. input price series and, based on that analysis, concluded that the input series are cointegrated—that there is no evidence to support the contention that LEC input price series moves differently from the U.S. input price series except for spurious random fluctuations.



**Figure 1**  
**LEC and US Input Prices Track Each Other Closely**

input price differential has returned to a zero mean in the 1989-1992 period and (iii) that the input price differential in the 1960-1980 period is the same as the differential in the 1990-1992 period. Thus, further applications of the Bush-Uretsky dummy variable method show that the Bush-Uretsky data do not support the hypothesis of a one-time shift in the input price differential at divestiture.<sup>16</sup>

<sup>16</sup> Duncan does not regard any of these dummy variable tests as dispositive tests of the hypothesis that the input price differential changed at divestiture or differs from zero. In Duncan's view, the proper test of the hypotheses that the input price differential is zero and has not changed is to perform a time series analysis of the differential and test whether the series is stationary and has a zero mean. In his California testimony, he showed that the data can reject neither hypothesis, so that the data are consistent with a data generating process that is stationary (constant over time) and has zero mean (so that the input price growth for the telecommunications industry equals that of the U.S. as a whole).

The two key questions to be answered are (i) whether LEC input price growth differs from the overall U.S. input price growth over the long run and (ii) whether the input price differential has changed since divestiture from its long run average. One simple way to address these questions is to create an index of each series and observe if, when and how LEC and U.S. input prices deviate from one another. These seemingly contradictory statistical results are then readily explainable given a picture of the data. Figure 1 shows LEC and U.S. input price indices developed using the Christensen 1 data set for the 1949-1992 period.

The input price indices track each other very closely from 1949 to 1979. LEC input prices then grow more rapidly than U.S. input prices from 1980 to 1983, more slowly from 1984 to 1989 and more rapidly again from 1990 to 1992. Relying on an artful choice of dummy variables, one could easily, but incorrectly, conclude that the relationship between LEC and U.S. input prices changed permanently at divestiture, but the evidence shows that (i) the change did not begin in 1984 and (ii) the change was not permanent, reversing itself in the 1990-1992 period. The data simply do not show a one-time, permanent change in the relationship between LEC and U.S. input prices in 1984. From the evidence shown in Figure 1, it would be impossible to argue that the mean input price differential growth rate for the 1984-1990 period would be the best forecast of future input price differential growth rates. On the contrary, the evidence suggests that a one-time deviation from historical norms has reversed itself and that U.S. and LEC input price changes should now again approximately equal one another. If there was a shift, it was temporary and is now over.

In addition, the data used to measure the input price differential were not collected for this purpose and are unsuited for this use in several ways. First, as explained by Dr. Christensen, the U.S. input price series are calculated using a different treatment of capital prices from the LEC input price series. Thus, in the post-divestiture period when interest rates fell but corporate profit rates remained relatively constant, the difference between measured U.S. and LEC input price changes overstated the actual difference between those changes. Moreover, the fact that both Christensen 1 and 2 data sets were spliced together

essentially at divestiture readily explains the observed "change" in the relationship between LEC and U.S. input price growth rates.<sup>17</sup> Thus, our ability to measure any hypothetical shift from these data is limited: measured differences in LEC and U.S. input price growth rates are at least partly due to differences in measurement methods.

### **C. Errors in Measuring Input Price and TFP Growth do not Cancel Out**

In USTA's Reply Comments filed in 1994, NERA presented both theoretical and empirical evidence that differences between measured LEC and U.S. industry input price growth rates are unreliable and more volatile than corresponding differences between LEC and U.S. total factor productivity growth rates. In addition, Christensen showed that U.S. and LEC capital prices were not comparable because they were calculated using different methodologies, and that apparent differences in growth rates could be ascribed to differences in methods of calculation rather than underlying differences in the true growth rates.

In their appraisal of this evidence, Bush-Uretsky replied that

- NERA has not shown that measurement errors in capital prices "introduce a bias into the input price series"<sup>18</sup> and that "although NERA has shown that the measurement problems could cause considerable year to year fluctuations, NERA has not shown that such fluctuations could make a six year period ... unreliable"<sup>19</sup> and that
- though BLS and Christensen measure capital costs differently, "an opposite bias of equal magnitude is contained in the TFP differential that USTA would use to set the X-Factor...[so that] the sum of the TFP differential and the input

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<sup>17</sup> The Christensen 1 data set essentially combines Bell System measurements (i.e., AT&T included with the RBOCs) from 1949-1979 with LEC measurements from 1984-1992, using two different LEC data sets between 1980 and 1983. The Christensen 2 data set combines the North Dakota LEC study (which uses a simplified measure of the price of capital) for the 1960-1984 period and the USTA LEC study for the 1985-1992 period.

<sup>18</sup> However, Christensen Associates showed that the capital price series in the U.S. National Income and Product Accounts produced a biased measure of the growth of U.S. capital prices and thus of the LEC-U.S. input price differential. See the Christensen Affidavit at 7-9.

<sup>19</sup> Generally an advocate of the use of a particular statistic for public policy purposes shows that the statistic is reliable, so that random errors of measurement do not lead to real changes in economic outcomes. NERA's alleged failure to show that the measured input price differential is unreliable does not meet even that minimal burden of proof.

price differential will be unbiased and that the X-Factor, which equals the sum, will be unbiased."<sup>20</sup>

Based on this record, ¶ 59 of the *FFN* seeks further information on problems in measuring input price changes, citing Bush-Uretsky's conclusion that

descriptions of problems in measuring changes in post-divestiture input prices fails (*sic*) to convince us that the problems are serious enough to warrant rejection of the measurements for use in calculating an X factor.

This conclusion, however, is incorrect and is based on (i) a misreading of the empirical evidence in the NERA study and (ii) a simple algebraic error in Attachment B to the Bush-Uretsky study.

First, input price differential data are clearly subject to much greater fluctuations than productivity differential data over the post-divestiture period. The empirical evidence regarding the input price differential presented in the various USTA filings and *ex partes* shows clearly that random fluctuations make data from a six or eight year period sufficiently unreliable that standard statistical tests cannot distinguish the mean differential from zero.<sup>21</sup> One might debate in a policy setting whether these statistics should commit the analyst to behave as if the hypothesis were true. However, one cannot seriously debate the empirical fact—quantified by the t-statistics—that “such fluctuations ... make a six year period ... unreliable,” particularly for use in predicting future values of the differential.

Second, Bush-Uretsky's conclusion regarding the comparability of LEC and U.S. input price series suffers from a critical algebraic error. In their Equation (2), reproduced below, the authors write the measured input price change ( $\%W^{US}$ ) as the sum of the true input price change ( $\%W^{*US}$ ) and a measurement error in input prices ( $\Delta_w$ )

(2) 
$$\%W^{US} = \%W^{*US} + \Delta_w .$$

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<sup>20</sup> Appendix F at 11.

<sup>21</sup> See, for instance, the affidavit of Dr. Laurits R. Christensen, “An Input Price Adjustment Would Be An Inappropriate Addition to The LEC Price Cap Formula” on behalf of the United States Telephone Association, February 1, 1995

The error  $\Delta_w$  is ascribed to the effect of profits on the measured change in U.S. input prices.<sup>22</sup> Bush-Uretsky define  $\%TFP^{US}$  as

$$(2.1) \quad \%TFP^{US} = \%W^{US} - GDP-PI$$

which can be interpreted as the measure of TFP growth associated with a correctly measured input price growth given by  $\%W^{US}$ . Substituting equation (2.1) into equation (2), they then obtain

$$(2.2) \quad \%W^{US} = GDP-PI + \%TFP^{US} + \Delta_w$$

The error arises in the next step where they (implicitly) assume that the last two terms in the above equation are equal to measured U.S. productivity growth. Using this notation, however, measured U.S. productivity growth ( $\%TFP^{US}$ ) differs from actual U.S. productivity growth ( $\%TFP^{*US}$ ) by a measurement error ( $\Delta_{TFP}$ ):<sup>23</sup>

$$(2.3) \quad \%TFP^{US} = \%TFP^{*US} + \Delta_{TFP}$$

Thus errors in measuring national input price growth and national TFP growth would cancel out and measured national input price growth would be equal to measured inflation plus measured national TFP growth:

$$(2.4) \quad \%W^{US} = GDP-PI + \%TFP^{US}$$

only if  $\Delta_w = \Delta_{TFP}$ . Comparing equations (2.2) and (2.4) above, we see that Bush-Uretsky have implicitly assumed that the measurement error in national input price growth is the same as the measurement error in national TFP growth (i.e., the measured growth rate differs from the actual growth rate by the same amount,  $\Delta$ , for both U.S. input prices and productivity). Thus, Bush-Uretsky incorrectly conclude that  $\Delta$  cancels out in their equation (6) in Attachment B only because they incorrectly assume that the same  $\Delta$  measures both the

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<sup>22</sup> We add the subscript W to Bush-Uretsky's  $\Delta$  to distinguish measurement error in input price growth from measurement error in TFP growth below.

<sup>23</sup> We add the subscript TFP to Bush-Uretsky's  $\Delta$  to distinguish measurement error in TFP growth from measurement in input price growth above.

error due to profits in the U.S. input price growth series and the error due to profits in the U.S. TFP growth series.

The assumption that an error due to the treatment of profits in U.S. accounting has the same effect on measured productivity growth as on measured input price growth is utterly incorrect. As explained in the NERA 1994 Reply Comments,

In a TFP study, input prices are used only to calculate the relative weights of different inputs used in construction of the quantity index of aggregate input. These weights are expenditure weights, where expenditure is the product of price and quantity. While calculation of labor and materials prices and expenditures is straightforward, the estimation of capital expenditure and the price of capital is quite complex. Moreover, for purposes of a TFP study, capital expenditures do not have to be measured with a significant level of precision: even though there are a number of ways to calculate such expenditures, the capital share of the input quantity index tends to be around 50 percent for LECs. And since it is the level that is important, fluctuations around 50 percent do not matter much in the estimate of the input quantity index.

In contrast, when the same formulas are used to calculate an input price index, the year to year change becomes very important. It is elementary that accurate calculation of changes is much more difficult than accurate calculation of levels.<sup>24</sup>

For example, small changes in capital equipment prices produce large changes in the measured price of capital, (as shown in Table 3 of the NERA Reply Comments) but have little effect on the relative size of capital expenditure and thus little effect on measured TFP. Such distortions are thus likely to have a much more significant impact on the growth of input prices than on the growth of TFP. In general, any error that distorts the *growth* of aggregate input prices but not the proportional mix of inputs will result in different  $\Delta$ s for equations (2) and (2.3) above. Thus, if one were to use the proposed input price differential in the calculation of  $X$ , measurement errors in national input prices would not cancel out,

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<sup>24</sup> National Economic Research Associates, Inc., "Economic Performance of the LEC Price Cap Plan: Reply Comments," filed as Attachment 4 to the *United States Telephone Association Reply Comments*, June 29, 1994, at 28. (NERA Reply Comments).

and errors in the input price differential would translate directly into errors in the measured value of  $X$ .

In summary, a correct reading of the theoretical and empirical evidence in the record supports the fragility of direct measures of the input price differential over the post-divestiture period. Setting  $X$  to reflect random fluctuations in the post-divestiture input price differential runs the risk of seriously penalizing price-cap regulated firms as interest rates begin to rise and LEC input prices—once again—begin to grow at a faster rate than those of the U.S. as a whole.<sup>25</sup>

### III. PRODUCTIVITY GROWTH CANNOT BE MEASURED FOR SUBSETS OF SERVICES

The *FFN* explores in ¶s 62-70 the possibilities of (i) measuring TFP growth for interstate services or for regulated services alone or (ii) adjusting a total company measure of productivity growth for differences in the relative rates of output growth for various services. Failing such adjustments, the *FFN* asks whether adoption of a productivity offset based on total firm TFP experience for interstate services alone would result in a deficit or windfall if intrastate prices were regulated using Part 36 costs.

As the *FFN* tentatively concludes,<sup>26</sup> TFP must be calculated on a total company basis because there is no economically meaningful way to assign portions of common facilities to individual services. To see this, suppose the regulated firm supplied only two identical services (interstate and intrastate usage) initially at equal volumes and equal prices, using identical facilities which could have both fixed and variable cost components. Suppose that over time, (i) demand for interstate usage doubled while demand for intrastate usage remained constant, and (ii) total input quantities increased by 40 percent. The resulting growth in TFP for the firm would be about 6 percent; using Törnqvist revenue weights,

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<sup>25</sup> In addition, changes in other LEC input prices could cause aggregate LEC input price growth to exceed that of average U.S. input prices.

<sup>26</sup> At ¶ 63.

aggregate output would have increased by about 46 percent while aggregate input quantities would have increased by 40 percent. Assuming input prices were unchanged, unit costs would fall by about 6 percent.<sup>27</sup>

How should this productivity growth be distributed—if it all—between interstate and intrastate usage? First, it should be clear by the symmetry of the assumptions that the change in variable cost is the same for interstate and intrastate usage: an additional minute of each service would increase total costs by exactly the same amount both before and after the change in output. Even though interstate demand growth is responsible in this example for the reduction in unit costs, that reduction inures equally to interstate and intrastate services. Thus if all costs were variable, unit costs for interstate and intrastate services would fall by the same amount (6 percent), and—in unregulated competitive markets—output prices for these services should fall by about the same amount. Second, if all costs were fixed, incremental cost would be zero in each jurisdiction and each additional minute of use would reduce unit costs by the same amount, irrespective of whether the usage were interstate or intrastate. Thus, it is pointless to ascribe faster TFP growth to one service compared with another.

**A. Productivity Growth Cannot be Measured Separately for Interstate Services**

The Christensen measures of historical LEC industry total factor productivity growth were calculated for (essentially) all inputs and outputs of the local telephone companies. Noting that the FCC regulates only interstate services, the *FFN* questioned the relationship between productivity growth for the firm as a whole and productivity growth for its interstate and intrastate services. In particular, the *FFN* requested comment on whether differential rates of output growth or profitability between interstate and intrastate services would affect measures of the historical interstate TFP growth rate and if there were some mechanism to adjust total company TFP growth estimates to account for these differences.<sup>28</sup>

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<sup>27</sup> We calculate growth rates using the difference between the natural logarithms of the levels.

<sup>28</sup> *FFN* at ¶ 62-68.